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Reactance Tube Modulation of Phase Shift Oscillators

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This paper describes a basic circuit for reactance tube modulation of phase shift oscillators. The design of suitable phase shift oscillators for frequencies from audio through the ultra-high frequencies is discussed. Experimental performance data derived from several types of frequency modulated phase shift oscillators are presented.

Introduction

FREQUENCY modulation of oscillators is finding wide-spread use in such diverse fields as FM broadcasting, telemetering systems for guided missiles and measuring apparatus for observing transmission frequency characteristics on cathode ray tubes. Design objectives for such oscillators may be listed briefly as:

1. A wide range of frequency modulation or, alternatively, high modulation sensitivity.
2. A linear relationship between instantaneous values of modulation input voltage and frequency deviation.
3. Freedom from accompanying amplitude modulation.
4. Inherent center frequency stability.
5. Ease and stability of adjustment.
6. A minimum number of components, none of which should be critical.
7. Modulation by dc, audio, or video inputs.
8. Operation anywhere in the frequency spectrum from low audio frequencies through the ultra-high frequency region.

The circuits described in this paper were developed in the course of an investigation of various frequency modulation circuits for use in visual transmission measuring systems. The oscillators had to be capable of linear modulation at 60 cycles over a ± 3 megacycle band at 25 megacycles and over a ± 9 megacycle band at 80 megacycles. Existing designs fell short of meeting the requirements with respect to several of the characteristics listed above. The reactance tube modulated phase shift oscillator circuit was found to perform satisfactorily in the transmission set and proved superior in many respects to all the other circuits tried. Tests of the circuit at other frequencies disclosed that the advantages were not peculiar to the frequency range and the following description is presented with the expectation that it may prove useful to others.

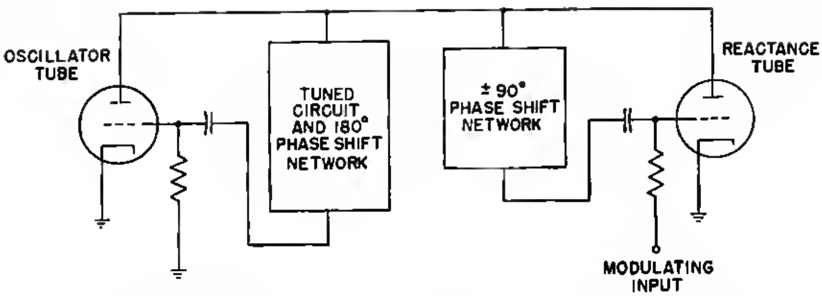


Fig. 1—Simplified schematic of conventional reactance tube modulated oscillator.

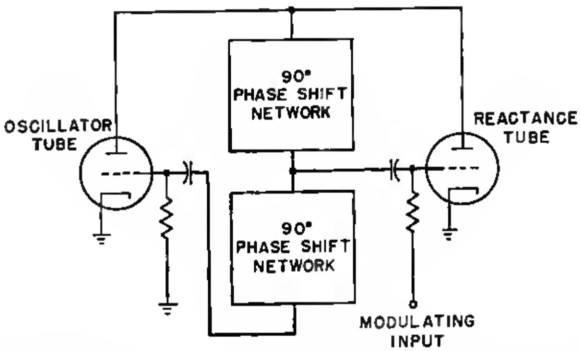
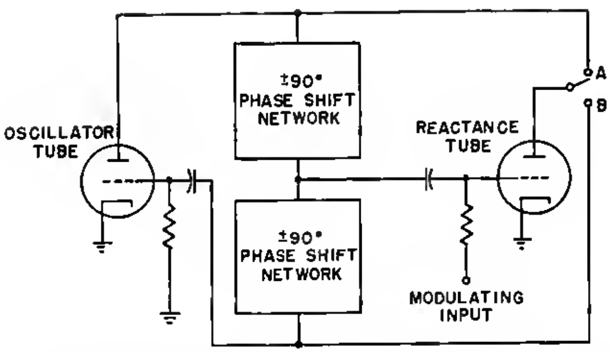


Fig. 2—Simplified schematic of phase shift reactance tube modulated oscillator.



TUBE CONNECTION	A		B	
NETWORKS	LEADING (+90°)	LAGGING (-90°)	LEADING (+90°)	LAGGING (-90°)
OSCILLATION FREQ.	DECREASES	INCREASES	DECREASES	INCREASES

Fig. 3—Direction of frequency deviation for increasing G_M of reactance tube.

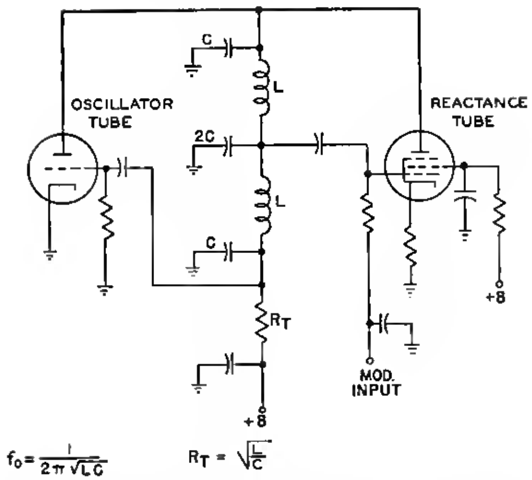


Fig. 4—LC reactance tube modulated phase shift oscillator.

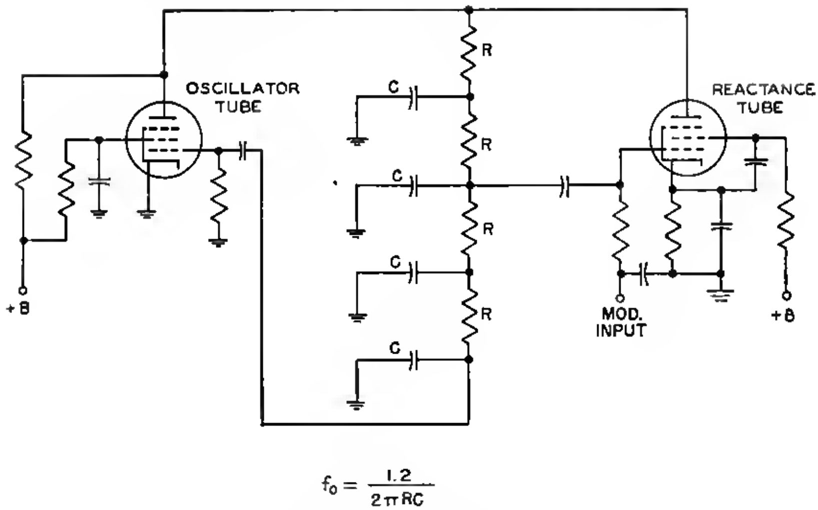


Fig. 5—RC reactance tube modulated phase shift oscillator.

Circuit Description

The theory and design of conventional reactance tube modulated oscillators has been discussed adequately in the literature[1,2,3]. A schematic in

[1] "Frequency Modulation" (book) by August Hund—McGraw-Hill, New York, 1942. Page 155.

[2] "Automatic Tuning, Simplified Circuits and Design Practice," D. E. Foster, and S. W. Seeley. *Proc. I. R. E.*, Vol. 25, 1937, page 289.

[3] ATC Systems—*Wireless World*, February 19, 1937, page 177.

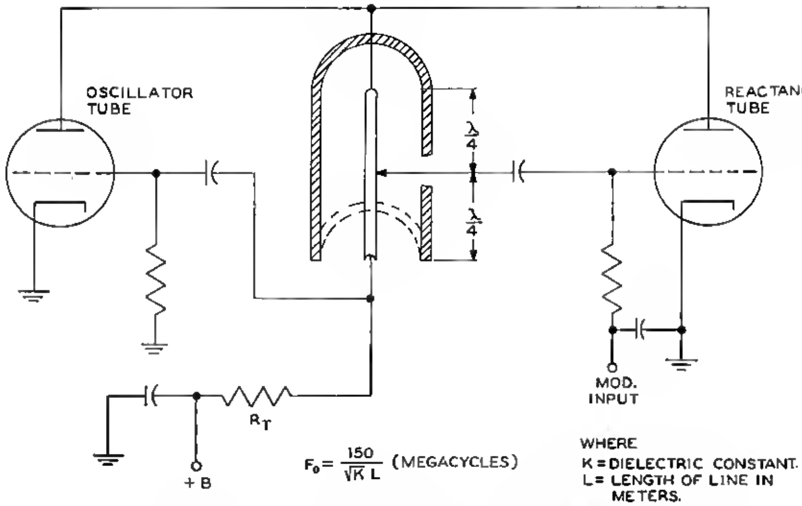


Fig. 6—Transmission line reactance tube modulated oscillator.

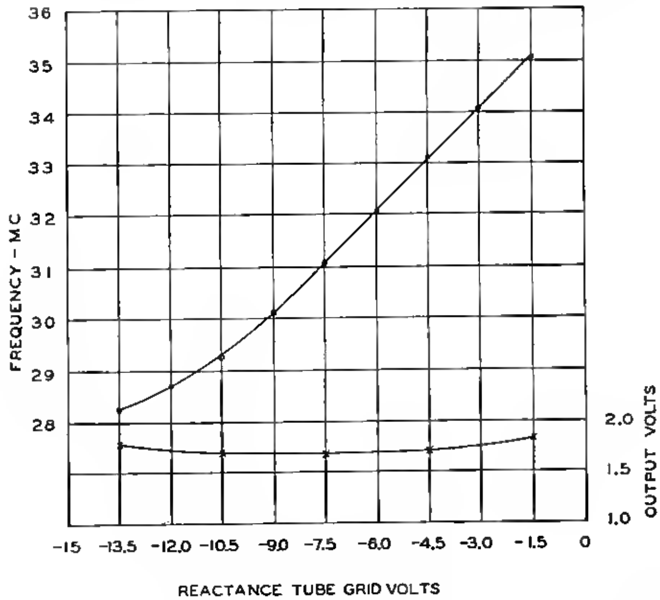


Fig. 7—Performance curves of typical LC reactance tube modulated phase shift oscillator.

simplified form is shown in Fig. 1. The input and output of a vacuum tube amplifier are connected together by a tuned circuit and feedback network which introduces 180° phase shift at the undeviated frequency F_0.

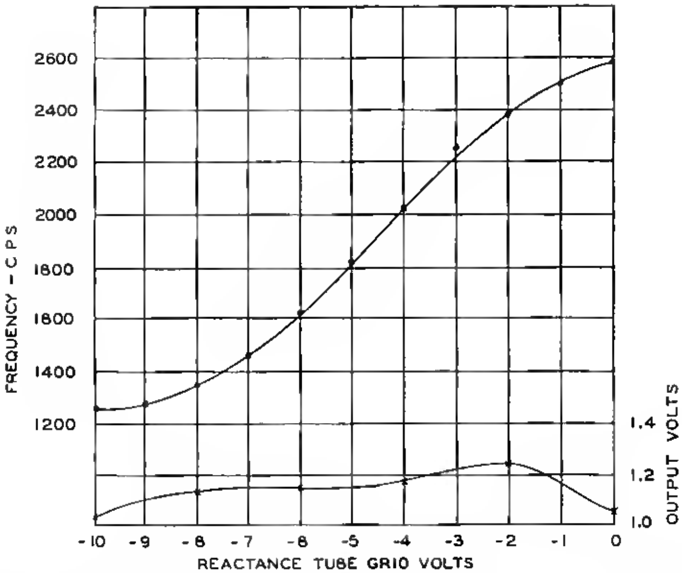


Fig. 8—Performance curves of typical RC reactance tube modulated phase shift oscillator.

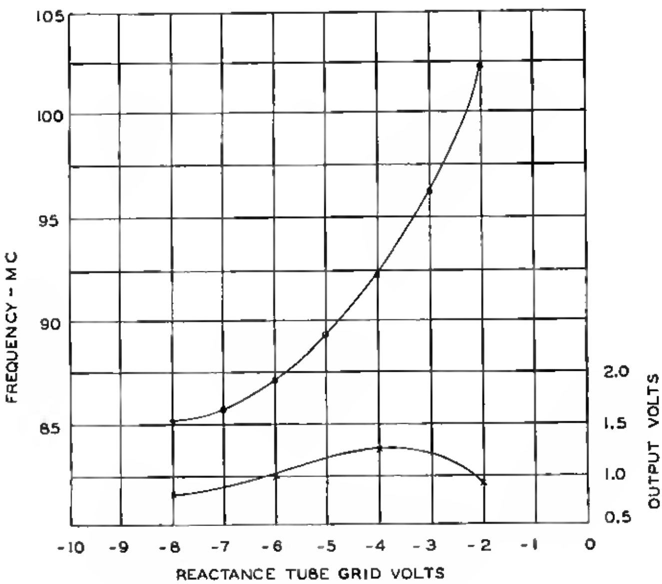


Fig. 9—Performance curves of typical transmission line reactance tube modulated oscillator.

An auxiliary path contains the reactance tube fed from a 90° phase shift network connected as shown. The direction of frequency deviation is determined by the sign of the 90° phase shift. The amount of the deviation is

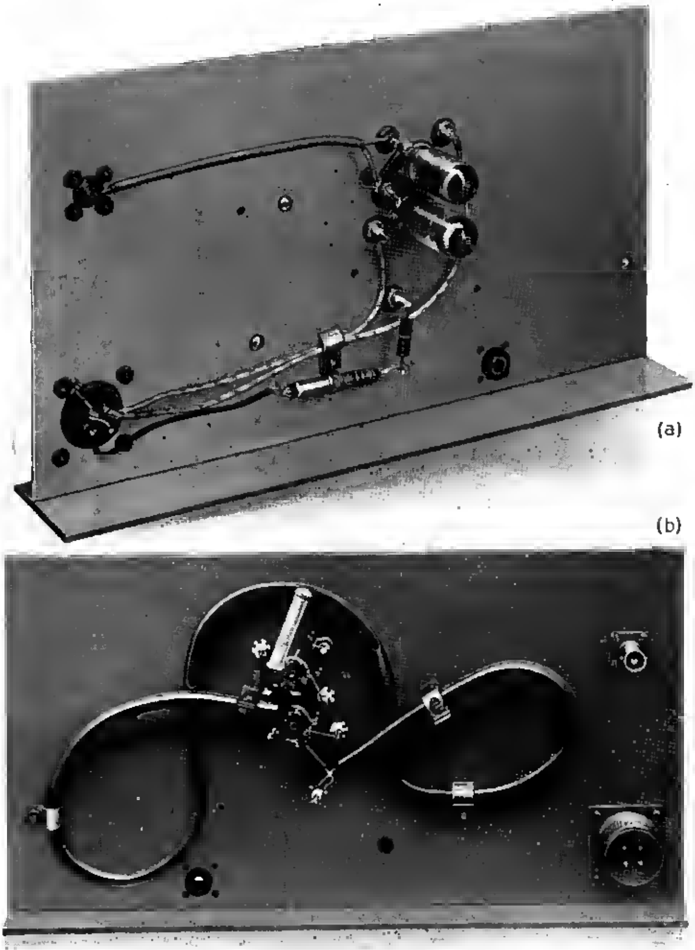


Fig. 10—Construction of transmission line reactance tube modulated oscillator. (a) Tube side. (b) Line side.

determined by the transconductance variation of the reactance tube, by the impedance across which the reactance tube is connected and by the loss in the 90° phase shift network. The linearity is a function of all of these factors. In general the frequency deviation may be increased by increasing

the L/C ratio in the oscillator tuned circuit, but only at the expense of frequency stability.

A simplified schematic of the reactance tube modulated phase shift oscillator is shown in Fig. 2. The mathematical theory of operation is analogous to that of the conventional reactance tube modulated oscillator, and the same methods of analysis may be applied. The 90° phase shift network required in the reactance tube grid circuit is a portion of the feedback network and provides half of the 180° phase shift required for oscillation. In this circuit the reactance tube is tightly coupled into the oscillating circuit with minimum loss in the 90° phase shift network. Hence small values of L/C ratio may be employed with a consequent increase in the inherent frequency stability. In practice, oscillators comparable in stability to good nonmodulated oscillators may be realized. The direction of deviation is determined by whether the phase of the reactance tube grid voltage leads or lags the reactance tube plate current. The permutations of connections and signs of the 90° phase shift networks are shown on Fig. 3 with the corresponding directions of frequency deviation.

The phase shift networks need not be of the LC lumped constant variety. For example, RC networks or sections of transmission line may be employed to particular advantage at the lower and higher frequencies respectively. A few of the many possible circuit configurations are shown in Figs. 4, 5, 6.

Experimental Data

Frequency deviation and output variation curves for some typical oscillators are shown in Figs. 7, 8, and 9.

The oscillator of Fig. 9 which was built by Mr. D. Leed, is shown in Fig. 10. The transmission line is a section of RG59U cable with the shield removed, encased in a copper tube with a slot for bringing out the center tap of the line to the reactance tube grid. The tubes are 6J6's with both sections connected in parallel.

Conclusion

Frequency modulated phase shift oscillators of several types have been described. These offer interesting possibilities for applications over a wide range of frequencies wherever stable, simple frequency modulated oscillators are required. With respect to range, linearity, and freedom from amplitude modulation their performance, as shown, is superior to that of conventional circuits and is at least equal to that of the complex circuits employed in the most critical applications.